Docket No. NEC-469-US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

Yutaka Bannai et al.

Serial No.: 09/963,530 **Group Art Unit**: 1746

Filed: September 27, 2001 **Examiner**: Jonathan Crepeau

For: SECONDARY BATTERY HAVING RADICAL COMPOUND ELECTRODE

Honorable Commissioner of Patents
Alexandria, VA 22313-1450

SUBMISSION OF VERIFIED ENGLISH TRANSLATION OF THE PRIORITY DOCUMENT

Sir:

Submitted herewith is a copy of the verified English translation of the Specification, Claims and Abstract, and the Declaration of Shozo Igarashi, dated July 20, 2004, that the English translation is a true English translation of the Japanese Application Number 2000-302669 filed October 2, 2000, upon which application the claim for priority is based.

Approval and acknowledgment of receipt are respectfully requested.

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re US Patent Application of: 09/963,530

Japanese Patent Application No.: 2000-302669

Japanese Patent Filing Date: October 2, 2000

VERIFICATION OF TRANSLATION

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

The undersigned, residing at SUITE 501, SALUTE BLDG., 72, YOSHIDA-CHO, NAKA-KU, YOKOHAMA, JAPAN, Japan, declares:

(1) that he knows well both the Japanese and English languages;

(2) that he translated the above-identified Japanese Application from Japanese to English;

(3) that the attached English translation is a true and correct translation of the above-identified Japanese Application to the best of his knowledge and belief; and

(4) that all statements made of his own knowledge are true and that all statements made on information and belief are with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereof.

July 20, 2004
Date

Shozo Igarashi
Signature

SHOZO IGARASHI
Typed name

【DOCUMENT NAME】	APPLICATION FOR PATENT
【REFERENCE NUMBER】	34601588
【DATE SUBMITTED】	October 2, 2000
【DESTINATION】	Commissioner, Patent Office
【INTERNATIONAL PATENT CLASSIFICATION】	H01M 4/02
	H01M 4/36
	H01M 10/40
【TITLE OF THE INVENTION】	BATTERY
【NUMBER OF CLAIMS】	13
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【INDICATION OF FEES TO BE PAID】

【Registration Number for Prepayment】 008707

【Amount of Fee】 21000

【LIST OF ARTICLE TO BE SUBMITTED】

【Name of Article】 Specification 1

【Name of Article】 Drawings 1

【Name of Article】 Abstract 1

【Number of General Authorization】 9709418

【NEED FOR PROOF】 Yes

[Name of Document] Specification
[Title of the Invention] Battery
[Scope of Claim for Patent]

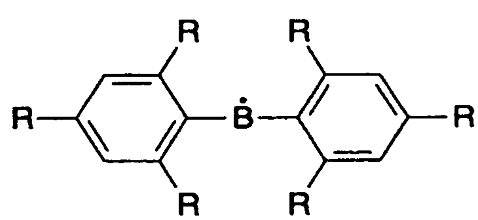
[Claim 1] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a boron radical compound.

[Claim 2] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having boron radicals in an oxidation state.

[Claim 3] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having boron radicals in a reduction state.

[Claim 4] The battery as set forth in any one of claims 1 to 3, characterized in that the boron radical compound has a radical on a boron atom combined with an aromatic group or an alkyl group.

[Claim 5] The battery as set forth in any one of claims 1 to 4, characterized in that the boron radical compound is represented by the accompanying formula (1):
[chemical 1]



(1)

(in the formula, R represents a hydrogen atom, a substituted hydrocarbon group or a non-substituted hydrocarbon group)

[Claim 6] The battery as set forth in any one of

claims 1 to 5, characterized in that the boron radical compound has dimesityl boron radicals.

[Claim 7] The battery as set forth in any one of claims 1 to 6, characterized in that a spin concentration of the boron radical compound is 10^{21} spins/g or more.

[Claim 8] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a sulfur radical compound.

[Claim 9] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in an oxidation state.

[Claim 10] A battery comprising a positive electrode, a negative electrode and an electrolyte, characterized in that at least one o active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in a reduction state.

[Claim 11] The battery as set forth in any one of claims 8 to 10, characterized in that the sulfur radical compound has a radical on a sulfur atom combined with an aromatic group.

[Claim 12] The battery as set forth in any one of claims 8 to 10, characterized in that the sulfur radical compound has a radical on a sulfur atom of a thianthrene derivative.

[Claim 13] The battery as set forth in any one of claims 8 to 12, characterized in that a spin concentration of the sulfur radical compound is 10^{21} spins/g or more.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a battery, more

particularly, to a battery with a high energy density and excellent in the stability and safety properties, where a radical compound is employed as a primary ingredient of active material.

[0002]

[Prior Art]

As the market of portable information terminals such as a note-type personal computer or a portable telephone set has been rapidly developed, smaller batteries with a larger capacity have been required. In order to meet this requirement, batteries have been developed where alkali metal ions such as lithium ions are employed as charged carriers and the electrochemical reaction associated with emission and reception of electric charges is utilized. Particularly, lithium ion batteries are used as batteries with a high energy density and having an excellent stability property in a variety of electronic equipment. In such lithium ion batteries, transition-metal oxide including lithium is used as active material to form a positive electrode and carbon is used to form a negative electrode, so that charging and discharging of electric charges are performed by utilizing occlusion of lithium ions in the active materials and emission of lithium ions therefrom.

[0003]

However, the lithium ion batteries use transition-metal oxide having a large specific gravity for positive electrodes, so that the weight energy density of the positive electrode is approximately 150 mAh/g, this is an insufficient value, which has attempted to develop large capacity batteries by using lighter material for electrodes. For example, U.S. Patent No. 4,833,048 and Japanese Patent No. 2715778 disclose a battery using an organic compound having a disulfide bond as positive-electrode active material. This battery utilizes electrochemical oxidation and reduction reaction in association with generation and dissociation of disulfide

bonds to perform a charging and discharging operation, and has a positive electrode formed by an element having a small specific gravity as a primary ingredient such as sulfur or carbon, so that some effect is exhibited in view of a battery with a high energy density. However, a dissociated bond has a small probability for recombination, and the stability property is insufficient.

[0004]

A battery using conductive polymers has been proposed as a battery using an organic compound as active material of an electrode. The battery using conductive polymers is based on the doping and undoping reaction principle of electrolytic ions with the conductive polymer. The aforementioned doping reaction is a reaction for stabilizing exyton such as charged solitons or polarons generated by an oxidation or reduction of conductive polymers using paired ions. The aforementioned undoping reaction is a reaction for oxidizing or reducing electrochemically exytons stabilized by means of the paired ions, which is a reverse reaction of the doping reaction.

[0005]

U.S. Patent No. 4,442,187 discloses a battery using conductive polymers as active material of a positive or negative electrode. This battery is constructed by only elements having small specific gravities, such as carbon and nitrogen, and is expected to be a large capacity battery. However, the conductive polymer has a nature that the exyton generated through oxidation and reduction reaction non-localizes in a broad range of π-electron conjugated system and interacts with each other, which limits the density of generated exyton to impose restrictions on a battery capacity. As a result, the battery using the conductive polymer as electrode material exhibits some effect in view of lighter weight, however, is insufficient in view of a large capacity battery.

As stated hereinbefore, in order to realize a large

capacity battery, batteries without using transition-metal oxide have been proposed. However, there is still not obtained a battery with a high energy density and having excellent stability property and safety property.

[0006]

[Problem to be Solved by the Invention]

Since a lithium ion battery using transition-metal oxide to form a positive electrode has an element having a large specific gravity, it is difficult in principle to manufacture a larger capacity battery than present ones. Owing to this, batteries without utilizing transition-metal oxide have been proposed, however, there is still not obtained a battery with a high energy density and having an excellent stability property and a safety property.

[0007]

An object of the present invention is therefore to provide a new battery with a high energy density and having an excellent stability property and a safety property.

[0008]

[Means for Solving the Problem]

In the battery provided with a positive electrode, a negative electrode and an electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a boron radical compound.

Also, in the battery provided with the positive electrode, the negative electrode and the electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having boron radicals in an oxidation state.

Also, in the battery provided with the positive electrode, the negative electrode and the electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active

material of the negative electrode includes a compound having boron radicals in a reduction state.

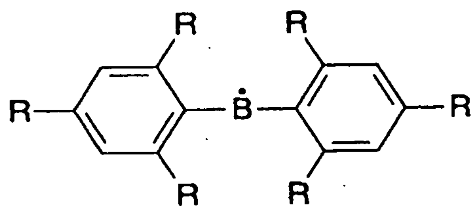
[0009]

Also, It is desirable that the boron radical compound has a radical on a boron atom combined with an aromatic group or an alkyl group.

Also, it is desirable that the boron radical compound is represented by the following formula (1).

[0010]

[chemical 2]



(1)

[0011]

(in the formula, R represents a hydrogen atom, a substituted hydrocarbon group or a non-substituted hydrocarbon group)

Also, it is desirable that the boron radical compound has dimesityl boron radicals.

Also, it is desirable that a spin concentration of the boron radical compound is 10^{21} spins/g or more.

[0012]

Also, in the battery provided with the positive electrode, the negative electrode and the electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a sulfur radical compound.

Also, in the battery provided with the positive electrode, the negative electrode and the electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in an oxidation state.

Also, in the battery provided with the positive

electrode, the negative electrode and the electrolyte, the present invention is characterized in that at least one of active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in a reduction state.

[0013]

Also, it is desirable that the sulfur radical compound has a radical on a sulfur atom combined with an aromatic group.

Also, it is desirable that the sulfur radical compound has a radical on a sulfur atom of a thianthrene derivative.

Also, it is desirable that a spin concentration of the sulfur radical compound is 10^{21} spins/g or more.

[0014]

[Mode of Carrying out the Invention]

Hereinafter, the present invention will be explained in detail.

Fig. 1 is a front view illustrating one example of a battery according to the present invention, and Fig. 2 is a cross-sectional view of the battery of Fig. 1. A battery 1 is constructed by a laminated body, where a negative electrode 5 that is formed by a negative electrode layer 4 and a negative electrode current collector 3 connected to a negative electrode terminal 2 and a positive electrode 9 that is formed by a positive electrode layer 8 and a positive electrode current collector 7 connected to a positive electrode terminal 6 are laminated by sandwiching a separator 10 impregnated with electrolyte. The laminated body is sealed by a sheathing member 11 formed by laminating film while the negative electrode and positive electrode terminals are exposed to the outside.

At least one of the negative electrode 5 and the positive electrode 9 includes a radical compound as a primary ingredient of active material of an electrode.

[0015]

The battery according to the present invention is

characterized by utilizing a radical compound, more particularly, a boron radical compound or a sulfur radical compound as a primary ingredient of active material of an electrode.

Also, the electrode active material generally has two states that are a starting state and an oxidized or reduced state through an electrode reaction, and the battery according to the present invention is characterized in that the electrode active material includes a radical compound in any one of the starting state and the oxidation or reduction state.

A charging and discharging mechanism of the battery according to the present invention is considered that a radical compound in the electrode active material turns reversibly from a radical state into an ion state and vice versa through an electrode reaction to store electric charges, however, its detail is not yet revealed.

[0016]

A boron radical compound is a compound including boron atoms having an unpaired electron, and a sulfur radical compound is a compound including sulfur atoms having an unpaired electron. Generally, radicals are chemical species rich in reactivity, and many of radicals extinguish in a certain lifetime through interaction with their surrounding materials, however, radicals can be stable in accordance with the resonance effect, the steric hindrance or the state of a solvation. Some of these stable radical compounds have a spin concentration of 10^{19} to 10^{23} spins/g measured by electron-spin resonance analysis, and some of the stable radical compounds have a spin concentration for a long time.

[0017]

In view of statistic-mechanical consideration, it is considered that any of chemical materials at room temperature has an atom species in a radical state. A radical concentration is generally measured through an electron-spin resonance spectrum. Although the spin

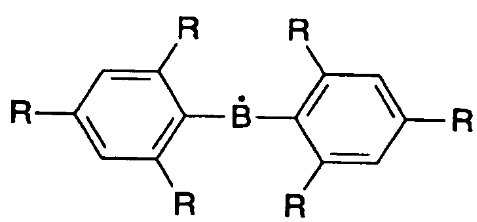
concentration of the radical compound of the present invention is not limited in particular, in consideration of usual non-radical compounds having the spin concentration of about 10^{16} spins/g, the spin concentration in an equilibrium condition is 10^{19} spins/g or more, usually 10^{21} spins/g or more. In an aspect of capacity, it is preferable that the spin concentration is kept more than 10^{21} spins/g. Also, in view of the stability property of the battery, the radical compound preferably a stable radical compound. Here, a stable radical compound is a compound having a long longevity of a radical.

[0018]

A boron radical compound according to the present invention is not limited in particular when a boron atom has a radical on itself in its molecular structure, however, in view of the stability property of the radical, it is preferable that the compound has a radical on a boron atom combined with an aromatic group or an alkyl group, and more particularly, it is preferable that the compound has a structure represented by the following formula (1). Moreover, it is preferable that the compound has a dimethyl boron radical represented by the following formula (2).

[0019]

[chemical 3]



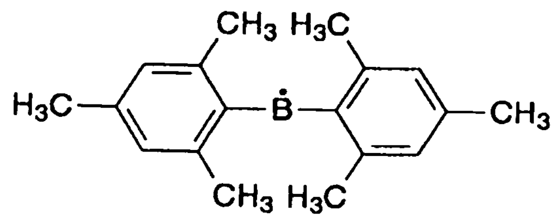
(1)

[0020]

(in the formula, R represents a hydrogen atom, a substituted hydrocarbon group or a non-substituted hydrocarbon group)

[0021]

[chemical 4]



(2)

[0022]

A sulfur radical compound according to the present invention is not limited in particular when a sulfur atom has a radical on itself in its molecular structure, however, in view of the stability property of the radical, it is preferable that the compound has a radical on a sulfur atom combined with an aromatic group or on a sulfur atom of a thianthrene derivative. Note that a sulfur radical compound generated at the cleavage or recombination due to an electrode reaction of a disulfide bond such as an S-S bond brings a reduction of the cyclic characteristics due to diffusion of sulfur atoms, which is not preferable in view of the stability of the battery, so that such a sulfur radical compound is not included in the sulfur radical compound of the present invention.

[0023]

In the battery of the present invention, the radical compound being a primary ingredient of an electrode active material is not particularly limited in view of operation in a solid state or in a molten state in a liquid solution. However, when the radical compound is used in a solid state, in order to suppress the reduction of the capacity of the battery due to melting into an electrolyte, it is preferable that the radical compound is insoluble in an electrolyte or has low-solvent properties. Also, the molecular weight of the radical compound of the present invention is not limited in particular.

The radical compound according to the present invention can be used individually or together with two different or more radical compounds. Furthermore, it can be used with other active materials.

[0024]

The battery according to the present invention is characterized by including a radical compound as a primary ingredient in at least one of active material of the positive electrode and active material of the negative electrode, and when the radical compound is used in any one of the active materials, the prior art active material can be used as an active material for the other electrode. For example, when a radical compound is used as a primary ingredient of the negative electrode active material, the positive electrode active material can be formed by using transition-metal oxide grains, a disulfide compound, a conductive polymeric compound or the like. The transition-metal oxide can be lithium-manganese oxide such as $LiMnO_2$, $Li_xMn_2O_4$ ($0<x<2$), etc., lithium-manganese oxide having a spinel structure, MnO_2, $LiCoO_2$, $LiNiO_2$, $Li_xV_2O_5$ ($0<x<2$) or the like, for example. The disulfide compound can be dithioglycol, 2,5-dimercapto-1, 3,4-thiadiazol, S-triazine-2, 4,6-trithiol or the like, for example. The conductive polymeric compound can be polyacetylene, polyphenylene, polyaniline, polypyrrole or the like, for example. In the present invention, these positive electrode active materials can be used individually or by combining them with each other. Also, it is possible to mix the prior art active material with a radical compound to use its mixture as a composite active material.

[0025]

On the other hand, when a radical compound is used as a primary ingredient of the positive electrode active material, the negative electrode active material can be formed by using carbon material such as graphite or amorphous carbon capable of absorbing and expelling lithium ions, metal material such as lithium metal or lithium alloy, an organic compound such as a conductive polymeric compound, or the like. The shape of these materials is not limited in particular. For example, lithium metal can be of a thin film state, of a bulk state, of a fiber state, of a flake state, of a hardened powder

state or the like.

[0026]

As explained above, the battery according to the present invention is characterized in that a radical compound contributes directly to an electrode reaction at the positive electrode or the negative electrode, so that the radical compound being a primary ingredient of an electrode active material can be used in any one of the positive electrode and the negative electrode. In view of the energy density, however, it is preferable to use the radical compound as the primary ingredient of the positive electrode active material.

Further, in view of the stability property, it is specifically preferable that an electrode reaction at the positive electrode during an electricity discharging is an electrode reaction where a radical compound is a reactant. Moreover, if a product of this reaction forms a combination with cations of electrolyte salt which will be stated later, further improvement of the stability property can be expected. Although these cations of electrolyte salt are not limited in particular in the present invention, lithium ions are preferable in view of the capacity.

[0027]

In the battery according to the present invention, when electrode layers including a radical compound are formed, in order to reduce its impedance, conductivity enhancing material and ion conductivity enhancing material can be mixed. The conductivity enhancing material can be carbon fine particles such as graphite, carbon black, acetylene black, etc., and a conductive polymeric compound such as polyaniline, polypyrrole, polythiophene, polyacetylene, polyacene, etc. The ion conductivity enhancing material can be a polymer gel electrolyte, a polymer solid electrolyte, etc.

[0028]

In the battery according to the present invention, in

order to enhance the binding force of structural materials of the electrodes, a binding agent can be used. The binding agent can be resin binder such as polyvinylidene fluoride, vinylidene fluoride-hexafluoropropylence copolymer, vinylidene fluoride-tetrafluoroethylene copolymer, stylene-butadiene copolymer rubber, polypropylene, polyethylene, polyimide, a variety of polyurethanes or the like.

[0029]

In the battery according to the present invention, in order to carry out the electrode reaction smoothly, a catalyst for assisting the oxidation and reduction reaction can be used. The catalyst can be a conductive polymeric compound such as polyaniline, polypyrrole, polythiophene, polyacetylene, polyacene, etc., a basic compound such as pyridine derivative, pyrrolidone derivative, benzimidazole derivative, benzothiazole derivative, acridine derivative, metal ion complex or the like.

[0030]

In the battery according to the present invention, as the electrode current collector material, various materials can be used to include metal such as nickel, aluminum, copper, silver, gold, aluminum alloy, stainless, etc., carbon material or the like. The shape of these materials is not limited in particular, and it is possible to use those of a foil state, of a plate state, of a mesh state and the like. Also, it is possible to impart a catalyst effect to the current collectors or to chemically bond the active materials with the current collectors.

Also, in order to prevent the above mentioned positive electrode and negative electrode from contacting each other, a nonwoven fabric or a separator made of porous film can be used.

[0031]

The electrolyte of the present invention is in charge of transferring charged carriers between the electrodes

and generally has the ion conductivity of 10^{-5} to 10^{-1} S/cm at room temperature. As the electrolyte of the present invention, one melting electrolyte salt in solvent can be utilized, for example. As the electrolyte salt of the present invention, metal salt like lithium salt can be used, for example, such as $LiClO_4$, $LiPF_6$, $LiBF_4$, $LiCF_3So_3$, $LiN(CF_3SO_2)_2$, $LiN(C_2F_5SO_2)_2$, $LiC(CF_3SO_2)_2$, $LiC(C_2F_5SO_2)_3$, etc. Also, as the solvent, organic solvent such as ethylene carbonate, propylene carbonate, dimethyl carbonate, diethyl carbonate, methyl ethyl carbonate, γ-butyrolactone, tetrahydrofuran, dioxolane, sulfolane, dimethyformamide, dimethylacetamide, N-methyl-2-pyrrolidone, etc. can be used. Additionally, these solvents can be used individually or two kinds of solvents or more can be mixed.

[0032]

Furthermore, as the electrolyte of the present invention, polymeric electrolyte can also be used. A polymeric compound used as polymeric electrolyte is a vinylidene fluoride polymeric compound such as polyvinylidene fluoride, vinylidene fluoride-ethylene copolymer, vinylidene fluoride-monofluoroethylene copolymer, vinylidene fluoride-trifluoroethylene copolymer, vinylidene fluoride-tetrafluoroethylene copolymer, vinylidene fluoride-hexafluoropropylence copolymer, vinylidene fluoride-hexafluoropropylence-tetrafluoroethylene terpolymer, etc., an acrylonitrile polymeric compound such as acrylonitrile-methylmethacrylate copolymer, acrylonitrile-ethylmethacrylate copolymer, acrylonitrile-methylacrylate copolymer, acrylonitrile-ethylacrylate copolymer, acrylonitrile-methacrylate copolymer, acrylonitrile-acrylate copolymer, acrylonitrile-vinylacetate copolymer, etc., polyethylene oxide, ethylene oxide-propylene oxide copolymer, or their acrylate polymer or methacrylate polymer, etc. These polymeric compounds can be used in a gel state impregnated with electrolyte, or only the

macromoles can be used.

[0033]

The sheathing member and the shape of the battery according to the present invention are not limited in particular, so that those of the prior art can be used. For example, the sheathing member can be a metal case, a resin case, and laminated films formed by metal foil such as aluminum foil, etc., and synthetic resin film, and the like. For example, the shape of the battery can be a cylindrical type, a rectangular type, a coin-shaped type, and a sheet-shaped type. However, the battery of the present invention is not limited thereto.

[0034]

The method for manufacturing the battery of the present invention is not limited in particular, so that a variety of methods can be used in accordance with materials. For example, in one method, a solvent and materials forming an electrode layer are mixed and formed into a slurry state to form the electrode on the electrode current collector by coating, and then a pair of electrodes sandwiching a separator is wrapped by the sheathing member by laminating or by winding. After that, electrolyte is injected and sealed. When a battery is manufactured, the battery is manufactured by utilizing radical compounds themselves or by utilizing compounds changing into a radical compound through a battery reaction. As an example of the compound changing into a radical compound through a battery reaction, lithium salt and sodium salt that are anions obtained through reduction of a radical compound are considered. In the present invention, the battery can also be manufactured by utilizing these compounds changing into radical compounds through a battery reaction.

[0035]

In the present invention, other manufacturing conditions of a forming method of terminals connected to electrodes, a sheathing method, etc. can be those of the prior art.

In the present invention, the laminating method of electrodes is not limited in particular, so that some method such as a multi-ply lamination method for forming the positive and negative electrodes opposed to each other, a method for winding laminated electrodes, etc. can be used.

[0036]

The present invention has found that radical compounds, more particularly, a boron radical compound or a sulfur radical compound can be utilized as a primary ingredient of electrode active material. When the radical compound is formed by only lightweight elements such as carbon, hydrogen or oxygen, the battery with a high energy density per weight can be obtained. Moreover, in the present invention, since only the positions of radicals contribute to reaction, the cyclic characteristics do not depend on the diffusion of active materials, thus exhibiting an excellent stability property. Also, in radical compounds, since unpaired electrons reacting as active materials localize in radical atoms, the density of radicals being reaction positions can be increased, thus realizing a battery with a high energy density.

[0037]

[Embodiment]

Hereinafter, the present invention will be explained in detail in accordance with embodiments, however, the present invention is not limited to those embodiments.

(Embodiment 1)

In an argon gas-atmosphere globe box, dimethoxyethane solution including dimesityl boron radicals is mixed with graphite powder as ancillary material for conductivity so that the mixture ratio (weight ratio) of the dimesityl boron radicals to the graphite powder is 2:1, and then the mixed liquid is homogenized. After that, the mixed liquid is coated on an aluminum foil to which an electrode terminal is previously connected, and the dimethoxyethane is removed by drying, thereby forming an electrode.

[0038]

Next, after the vinylidene fluoride-hexafluoropropylence copolymer is melted in the tetrahydrofuran, this liquid solution is mixed with the ethylene carbonate-propylene carbonate mixture solvent including $LiPF_6$ of 1 mol/l so that the mixture ratio (weight ratio) of the liquid solution to the ethylene carbonate-propylene carbonate mixture solvent is 2:1, and then the mixed liquid is homogenized. After that, the mixed liquid is coated on a glass plate, and the tetrahydrofuran is removed by drying, thereby forming the polymeric electrolyte layer.

Next, cutting operations are performed on the electrodes including boron radicals, the polymeric electrolyte layer, and the lithium laminated cupper foil in advance connected to the electrode terminal, to form predetermined shapes, respectively. The electrode layer including boron radicals and the lithium are laminated so as to oppose to each other via the polymeric electrolyte layer. After that, a sealing operation is carried out by using a laminate film as the sheathing member, thus manufacturing a battery.

[0039]

In the above-manufactured battery, the electrode including boron radicals is a positive electrode and the cupper foil laminated with the lithium is a negative electrode. When the charging and discharging of electric current is repeated under the current density of 0.1 mA/cm^2, it was confirmed that the battery could serve as the battery until 10 cycles of charging and discharging operations.

Also, the measurement of an electron-spin resonance spectrum of the dimethoxyethane solution including dimesityl boron radicals used in the battery of the present invention confirmed that the spin concentration was 10^{21} spins/g or more.

[0040]

(Embodiment 2)

In an argon gas-atmosphere globe box, acetonitrile solution including p-bis(methylthio)benzene radicals is mixed with graphite powder as ancillary material for conductivity so that the mixture ratio (weight ratio) of the p-bis(methylthio)benzene radicals to the graphite powder is 2:1, and then the mixed liquid is homogenized. After that, the mixed liquid is coated on an aluminum foil to which an electrode terminal is connected in advance, and the acetonitrile is removed by drying, thereby forming an electrode.

[0041]

Next, after the vinylidene fluoride-hexafluoropropylence copolymer is melted in the tetrahydrofuran, this liquid solution is mixed with the ethylene carbonate-propylene carbonate mixture solvent including $LiPF_6$ of 1 mol/l so that the mixture ratio (weight ratio) of the liquid solution to the ethylene carbonate-propylene carbonate mixture solvent is 2:1, and then the mixed liquid is homogenized. After that, the mixed liquid is coated on a glass plate, and the tetrahydrofuran is removed by drying, thereby forming a polymeric electrolyte layer.

Next, cutting operations are performed on the electrodes including sulfur radicals, the polymeric electrolyte layer, and the lithium laminated cupper foil in advance connected to the electrode terminal, to form predetermined shapes, respectively. The electrode layer including sulfur radicals and the lithium are laminated so as to oppose to each other via polymeric electrolyte layer. After that, a sealing operation is carried out by using a laminate film as the sheathing member, thus manufacturing a battery.

[0042]

In the above-manufactured battery, the electrode including sulfur radicals is a positive electrode and the cupper foil laminated with the lithium is a negative

electrode. When the charging and discharging of electric current is repeated under the current density of 0.1 mA/cm^2, it was confirmed that the battery could serve as the battery until 10 cycles of charging and discharging operations.

Also, the measurement of an electron-spin resonance spectrum of the concentrated sulfuric acid solution including p-bis(methylthio)benzene radicals used in the battery of the present invention confirmed that the spin concentration was 10^{21} spins/g or more.

[0043]

[Effect of the Invention]

As explained hereinbefore, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a boron radical compound, the battery has a high energy density and is excellent in the stability and safety properties.

Also, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a compound having boron radicals in an oxidation state, the battery has a high energy density and is excellent in the stability and safety properties.

Also, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a compound having boron radicals in a reduction state, the battery has a high energy density and is excellent in the stability and safety properties.

[0044]

Also, if the boron radical compound is a compound

having a radical on a boron atom combined with an aromatic group or an alkyl group, the stability of the battery is further improved.

Also, if the boron radical compound is a compound shown in the above-stated formula (1), the stability of the battery is further improved.

Also, if the boron radical compound has dimesityl boron radicals, the stability of the battery is further improved.

Also, if the spin concentration of the boron radical compound is 10^{21} spins/g or more, the obtained battery has a large capacity.

[0045]

Also, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a sulfur radical compound, the battery has a high energy density and is excellent in the stability and safety properties.

Also, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in an oxidation state, the battery has a high energy density and is excellent in the stability and safety properties.

Also, in a battery provided with a positive electrode, a negative electrode and an electrolyte according to the present invention, since at least one of active material of the positive electrode and active material of the negative electrode includes a compound having sulfur radicals in a reduction state, the battery has a high energy density and is excellent in the stability and safety properties.

[0046]

Also, if the sulfur radical compound is a compound

having a radical on a sulfur atom combined with an aromatic group, the stability of the battery is further improved.

Also, if the sulfur radical compound is a compound having a radical on a sulfur atom of a thianthrene derivative, the stability of the battery is further improved.

Also, if the spin concentration of the sulfur radical compound is 10^{21} spins/g or more, the obtained battery has a large capacity.

[Brief Description of the Drawings]

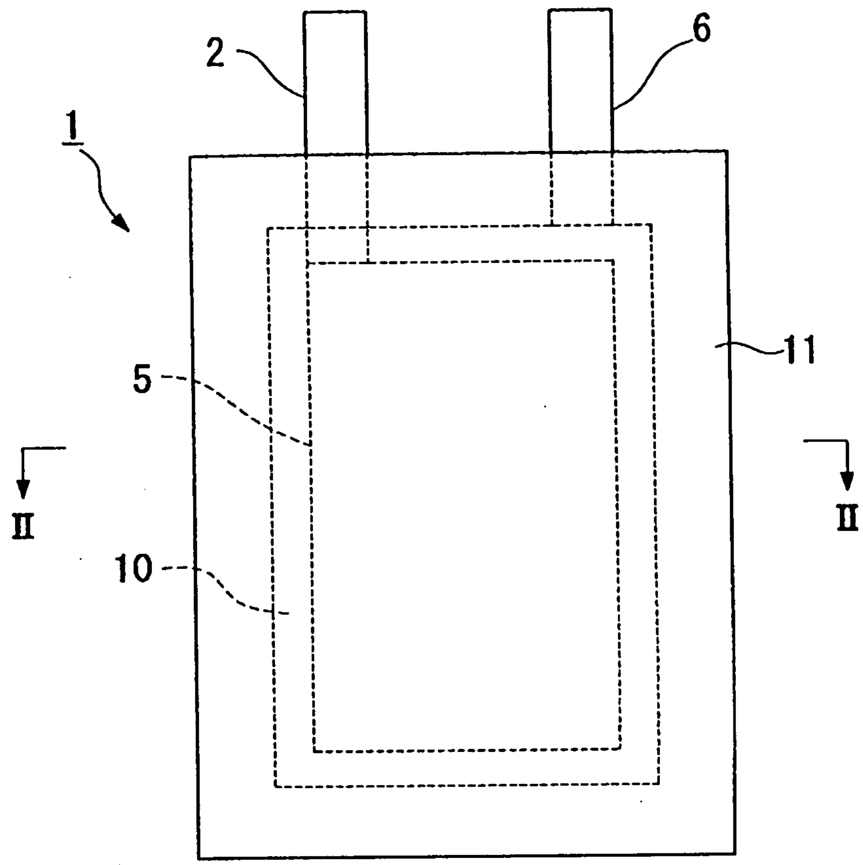
[Fig. 1] A front view illustrating one example of a battery according to the present invention.

[Fig. 2] A cross-sectional view taken along the line II-II of Fig. 1.

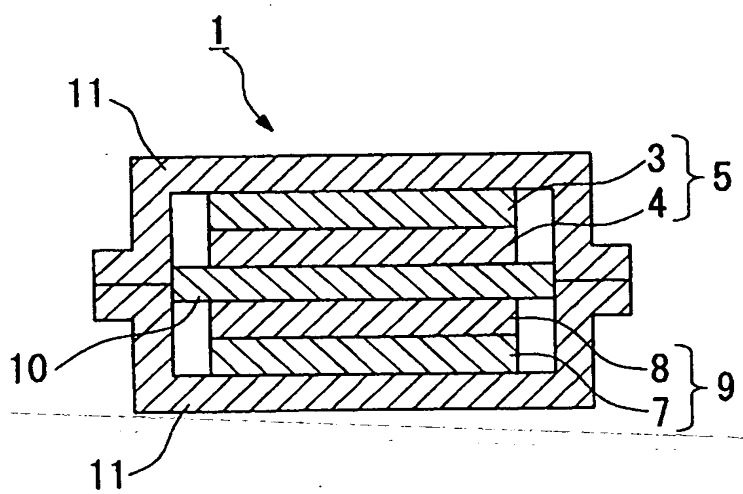
[Brief Description of the Symbols]

1 battery
5 negative electrode
9 positive electrode
10 separator impregnated with electrolyte

【書類名】 図面 Drawings
NAME OF DOCUMENT
【図１】
Fig. 1



【図２】
Fig. 2



[Name of Document] Abstract
[Abstract]
[Problem] To provide a new battery with a high energy density and excellent in the stability and safety properties.
[Means for Solving the Problem] In a battery 1 provided with a positive electrode 9, a negative electrode 5 and a separator 10 impregnated with electrolyte, at least one of a positive electrode active material and a negative electrode active material includes a boron radical compound or a sulfur radical compound.
[Elected Figure] FIG. 2